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ABSTRACT

Today, although much debate surrounds the effectiveness of including graphics in Web-based distance education courses, most course authors agree that such courses should productively engage students so that quality of learning actually occurs. But what is productive engagement in a world of electronic communication and text? This paper offers a possible answer to this question by providing evidence that the use of graphics can enhance online teaching. The evidence includes a description of: the use of four different visualization types and techniques as instructional tools; the positive perceptions of 22 undergraduate students toward the use of these types and techniques; and the beneficial impact of their use on learning outcomes in an online undergraduate science course. (Contains 12 references.) (Author)

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Anatomy of a Web-based Course: How Visualization Types & Techniques Can Impact Student Engagement & Learning Outcomes

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Abstract: Today, although much debate surrounds the effectiveness of including graphics in web-based distance education courses, most course authors agree that such courses should productively engage students so that quality learning actually occurs. But just what is productive engagement in a world of electronic communication and text? This paper offers interested readers with a possible answer to this question by providing evidence that the use of graphics can enhance on-line teaching. The evidence includes a description of: the use of four different visualization types and techniques as instructional tools, the positive perceptions of 22 undergraduate students towards the use of these types and techniques, and the beneficial impact of their use on learning outcomes in an on-line undergraduate science course.

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Introduction

In 1998, the Department of Poultry Science at the University of Arkansas, Fayetteville was awarded a United States Department of Agriculture (USDA) Higher Education Grant to address a growing instructional void in introductory poultry science. The objective of this project was to address the demand for this instructional need by developing two web-based poultry production courses that would cover the management of broilers, turkeys, breeders and layers. The Internet was chosen as the platform for course delivery because it is asynchronous and may be accessed from any connected site around the world. A content expert, an instructional designer and a graphic artist carefully reviewed a variety of instructional techniques and determined that a combination of visualization types and techniques could aid the learning process in the proposed on-line courses. Their unique instructional interface combined the use of static graphics, hypertext pop-ups, animation and concept mapping exercises to establish greater interaction or engagement between the students and course content. After the first course (Broiler & Turkey Production) was developed and implemented, the impact or benefit of these visualization types on the learning process was explored through document analysis and student interviews within a case study format.

Theoretical Underpinnings

The choice to use visualization as a method to engage students was based upon a review of two separate bodies of research and corresponding literature that assert that the visual representation of information increases a student's ability to learn in text-based environments. The first body of research addresses visual literacy, the second body addresses the development of mental models.

In regards to visual literacy, Levie and Lentz (1982) provided a comprehensive meta-analysis that addressed the effects of illustrated texts on learning by summarizing the results of 155 separate experimental comparisons.

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> Forty-six of those (155 studies) studies compared learning from illustrated text material versus (learning) from text alone. In all but one of these 46 cases, the group mean for those reading illustrated text was superior to that of the group reading text alone...in 39 of the 46 comparisons, the difference was statistically significant...and the average group score for the illustrated-text group was 36% better than for text -alone groups (Levie & Lentz, 1982, p. 198).

A deeper examination of the impact of the use of graphics and illustrations on learning from textbooks was detailed by Braden (1996) and Rieber (1994). These authors both discussed Paivio's 1971 Dual Coding Theory of memory and cognition in detail. In essence, Dual Coding Theory postulates that humans encode information to long-term memory both verbally and visually, and that verbal concepts are hung on nonverbal pegs in memory; i.e., imagery is the effective variable in recall of concrete verbal/written information. Further, "this means that if some piece of information is coded both visually and verbally, the probability of retrieval is doubled" (p. 113). Dual Coding Theory ties nicely to the research on mental representation as discussed by Winn and Synder (1996).

In 1996, Winn and Synder asserted that cognitive psychology and science research may be divided into two major categories which link visual imagery and the creation of mental models to learning: mental processes and mental representation. According to Winn and Synder their review of the literature in this area supports the argument that individuals learn new information and solve problems by creating their own visual metaphors or envisioning complex processes. According to their analysis of Salmon's research, human thinking "uses various symbol systems as tools" to gain new knowledge (p. 117).

Designing Instructional Graphics

The effective design of instructional graphics is best achieved when it is anchored within a specific learning theory. Thus, it is important to note that while Levis and Lentz's (1982) meta-analysis may be viewed independently from any specific learning theories, Dual Coding Theory and mental representation are obviously best understood when related to cognitive and constructivist learning theories. An insightful theory-based guide that addresses these issues was published by Lloyd Rieber in 1994. In his book, *Computer, Graphics & Learning*, Rieber suggested that Gagnes's events of instruction support five applications of graphics to teach that lie within the cognitive-constructivist continuum: "cosmetic, motivation, attention-gaining, presentation and practice" (p. 45). Applying Gagne's events of instruction, Rieber asserts that content experts and instructional designers should include graphics in instructional materials in conjunction with verbal/written content to serve precise instructional functions and only if they fulfilled specific instructional objectives. Further, Reiber asserted the function of a graphic may be arbitrary or may be used to create a realistic representation or an analogy. Representational graphics depict reality or a simplified version of it as seen in Figures 1 and 4. Arbitrary graphics can be graphs or charts, etc. or may depict a mental model of a system or phenomena as seen in Figures 2, 3 and 5.

Rieber (1994) also asserted that the research on visually literacy can be viewed according to Blooms' Domain of Learning Taxonomy. Reiber argued that cosmetic and motivational graphics impact the affective domain while attention-gaining, presentation and practice graphics impact the cognitive domains. Further, effective cognitive domain graphics gain and focus student attention selectively. I.e., effective attention-gaining and presentation graphics help students to filter out external distractions, but should not be a source of distraction or cognitive overload themselves. (Cognitive overload happens when too much information is presented all at once.) Effective practice graphics support students in higher-level cognitive processes such as the integration of new information into prior knowledge.

Rieber's review of research concerning the use of instructional animations revealed that little research has been done in this area. However he was still able to make some important points. Rieber asserted that as with static graphics, animations should be used "to demonstrate or elaborate concepts, rules or procedures" (p. 50). In addition, he highlighted two special effects produced by this type of graphic based upon his own research in this area. Animations are able to show changes over time and changes in direction or the trajectory of an object or phenomena.

This paper focuses on the use of graphics for attention-gaining, presentation and practice. Another important aspect of the use of graphics in web-based courses that is not addressed by this study is user interface design. Navigation disorientation negatively affects learning outcomes and can be very frustrating to for the learner. This topic is extremely important and as such should be examined separately.

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Description of the Visualization Types and Techniques

Effective Attention-Gaining Presentation with Static Visuals, Hypertext Pop-ups and Animation

The following examples represent a sequence of web pages in a module within the first course that covers physiology. This module teaches students about temperature regulation in poultry by using static visuals, hypertext pop-ups and animation.

Figure 1 illustrates the two basic or primary features of poultry physiology important to homeostasis (the ability to maintain a constant body temperature) through a static graphic. In this case the design of the graphic was intentionally kept quite simple in order to focus students on basic pre-requisite information/knowledge. The graphic visualizes the most important facts presented. The student's instructional objective was to grasp that poultry, like other mammals, are warm-blooded and must maintain a nearly constant inner body temperature (around their internal organs, or core).

Figure 1: Static Visuals

Figure 2 guided students to build a deeper understanding of the physiology of homeothermic animals by engaging students with hyper-text pop-ups windows. Clicking on each of the zones activated the appearance of a second image that contained additional information as seen in Figure 3. A bird's thermal environment may be described by several temperature zones. Different species' physiological reactions to a particular temperature may differ, but many animals go through similar behavioral and physiological changes as temperatures increase or decrease. The student's instructional objective was to describe each of the temperature zones to which poultry may be exposed, listing the thermoregulatory mechanism(s) that might be used, including specific examples.

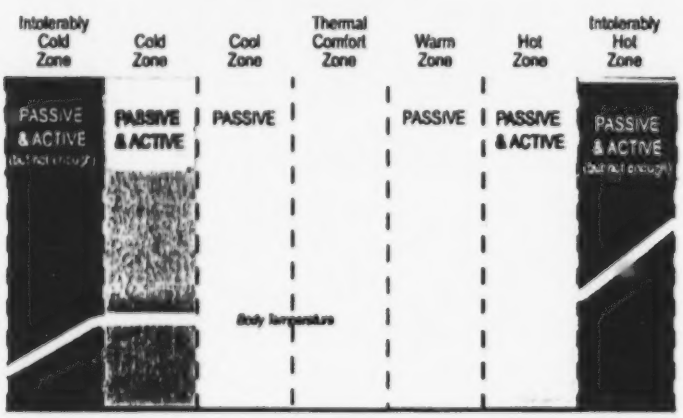

Figure 2: Hyper-text pop-up interaction

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Intolerably Hot Zone

In this zone, an animal has used up all active and passive thermoregulatory mechanisms to stay cool. The animal cannot sustain its body temperature for very long, and death will eventually result.

Figure 3. Pop-up Hypertext/Second Browser Window for Intolerably Hot Zone Bar
(A mouse click on the red bar in Figure 3 causes this information to pop-up along with Figure 3.)

Figure 4 presents two important definitions with hypertext pop-up windows and animation. A mouse click on either of the two hyper-linked terms highlighted in blue (vasoconstriction and vasodilatation) activated a second pop-up browser window that revealed a graphic illustration of the concept. In this case the pop-up illustrations were animations. These hypertext pop-up animations emphasized key concepts by prompting students to attend to and explore important terms and definitions. The student's instructional objective was to define the terms vasoconstriction and vasodilation, and indicate how heat flow from the core through the physiological shell is impacted by these processes. Each of the simple two part animations revealed a progression in temperature change specific to the each of the two terms presented. The animations presented students with the normal state of poultry at two temperatures. A graphic representation of a thermometer changed to correspond with physiology changes in the poultry as the temperature changed. The use of animations to teach these concepts provided an excellent opportunity for the students' to learn an invisible and complex scientific phenomena that could not be demonstrated otherwise. In this case the animations are able to show changes over time and changes in direction or the trajectory of a phenomena.

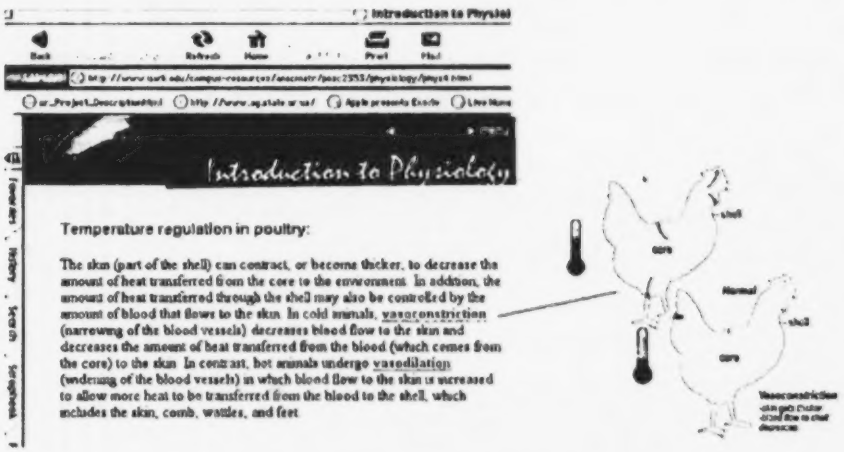
Introduction to Physiology
Temperature regulation in poultry:
The skin (part of the shell) can contract, or become thicker, to decrease the amount of heat transferred from the core to the environment. In addition, the amount of heat transferred through the shell may also be controlled by the amount of blood that flows to the skin. In cold animals, vasoconstriction (narrowing of the blood vessels) decreases blood flow to the skin and decreases the amount of heat transferred from the blood (which comes from the core) to the skin. In contrast, hot animals undergo vasodilation (widening of the blood vessels) in which blood flow to the skin is increased to allow more heat to be transferred from the blood to the shell, which includes the skin, comb, wattles, and feet.
shell
core
Normal
shell
core

Figure 4: Hypertext Pop-ups and Animation

Effective Practice with Concept Mapping Exercises

Figure 5 shows a detail of a concept map. Concept mapping exercises were imbedded into the course's content where ever applicable, to force students to articulate and reevaluate their knowledge by creating a mental model. These exercises represent graphics used to promote higher-level cognitive

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processes. Concept maps graphically illustrate relationships between ideas and their use in traditional classroom settings has been shown to greatly aid students in the process of restructuring their own knowledge and/or expanding their own conceptual understanding (Novak & Gowin, 1984; Novak & Musonda, 1984; Kennedy & McNaught, 1997). Within a concept map, two or more concepts are linked by words that describe their relationship. A concept is "a perceived regularity in events or objects or records, designated by a label" (Novak & Wandersee, 1990, p. 29). The student's instructional objective was to design a concept map that described the transitions a bird undergoes in each of the temperature zones, including references to passive and active thermoregulatory mechanisms, using real-world examples of different types of heat transfer.

Figure 5: Concept Map Detail from Expert Map

Sample & Methods

The developed course (Broiler & Turkey Production) contained eight sections of content presented within a modular format: historical insight, hatchery operations, brooding management, grow-out management, housing, physiology, introduction to nutrition, and financial aspects of poultry production. As stated previously, the visualization examples in this paper were all drawn from a single module that covered physiology. This module was chosen as the focus of this study because it contained the most difficult content within the course. Twenty-one students volunteered to participate in the case study conducted on the physiology module. All twenty-one students completed pre- and post-content knowledge concept mapping exercises and six students were chosen to participate in the nominal group interview process based upon their concept mapping exercises. The purpose of the interview was to: examine user patterns and probe student perceptions and attitudes. The sample in this study placed limitations upon the type of interview process that was conducted. A true focus group could not be established because the participants knew each other and were not randomly selected. The choice of a nominal group interview process however was not seen as detrimental to the outcome of this study; nominal group interviews are particularly productive when researchers are seeking to provide consensus or recommendations concerning alternative solutions (Krueger, 1994, p. 19).

Student Perceptions of the Visualization Types and Techniques

All six of the interview participants asserted that the incorporation of static graphics, hypertext pop-ups, animation and concept mapping exercises within the poultry physiology content successfully increased their interest and engagement by causing the courseware's print-based interface to take on the

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role of the teacher or instructor. This is particularly noteworthy as one of the primary goals of this study was to determine if the use of graphics could establish greater interaction or engagement between the students and course content to compensate for the decreased dialogue between the students and instructor common in distance learning situations. For example, Lindsey talked about how the various components helped to take the place of face-to-face contact with the instructor by stating: "...the icons helped tremendously because if you don't understand something you could go into those icons, and it gave detailed information about whatever he [the instructor] may actually be talking about. If you don't have a teacher and you can't ask him...for some of the students in ACTA [the Arkansas Consortium for Teaching Agriculture] schools [pause] I know take some of ours classes and stuff [pause] if they don't have that, then it would be kind of difficult [pause] if you don't have a teacher there…so the icons helped tremendously."

Further, Mickey elaborated on how various visualizations caused the content to be more dynamic by saying: "The diagram [Figure 2 and 3] that he [another student/Ken] mentioned was really, really helpful. You could click on the different parts [temperature zones shown in graphic form] and get information, but there was also a line showing [pause] how they [the poultry] were able to change their body temperature. I memorized that line, and that way I did not have to memorize every zone. Also you could click on vasodilatation and vasoconstriction on another page for further details..."

In specific regard to the use of concept mapping exercises, although only three of the 6 interview participants specified that concept mapping was a useful tool that enhanced their learning experience, all of the participants asserted that completing the concept mapping exercises required them to: increase their interaction with the course content and re-think their ideas about poultry physiology. For example, Hank affirmed the impact of concept mapping on his learning experience by saying: "It was useful. It was definitely useful…I would have to say as far as the temperature changes and things like that go... "

And Lindsey remarked on the differences between learning from the content alone and learning by creating concept maps by saying: "I think [pause] just basically putting everything into an organized manner [pause] if you just read the material than you are just getting a whole bunch of material, but when you do the concept map it showed like what you started with and what you ended with [pause] it helped [me] to understand the material."

In addition, the following comments indicate that it was not just one particular kind of visualization, but the combination of the other visuals used with concept mapping that created a better on-line learning opportunity. Hank describes his use of a hypertext pop-up graphic that showed various temperature zones during the post-concept mapping exercise by saying: "Whenever I read through the stuff on the web on that certain page that told all the temperature zones and how [pause] what effect it had on each one [pause] that was basically how my concept map was set up. It had the chicken in the middle, and then it had all the temperatures branching out from that and telling if it was passive or active or neither or both [pause] and each of the temperature zones and how they effected the chicken..."

Tom also elaborated on how the combination of graphics within the courseware helped him to learn temperature regulation in poultry by saying: "When doing the concept map, I just noticed throughout the physiology section that they would have words highlighted if they were scientific terms, and when you clicked them a pop-up screen would come up. Sometimes it would be a graph and sometimes it would be a definition, but it would pretty much explain it."

Concept Mapping, Changes in Mental Models & Learning Outcomes

A quantitative scoring scheme designed by Novak and Gowin (1984) was used to evaluate two concept mapping exercises administered before and after the students studied the on-line poultry physiology materials (Edmondson, 1999, p. 25). The goal of this evaluation was two fold: revealing changes in student mental models of temperature regulation in poultry, and as an alternative method of assessment. In contrast to other types of graphic organizers, Novak's concept mapping emphasizes the importance of specifying the links between key concepts, including cross-links across branches of any given hierarchy and adding examples to anchor concepts to the real world (Trowbridge & Wandersee, 1999). The scoring scheme is shown in Table 1. Changes in concept mapping scores are shown in Table 2. Please note that the concept map scoring data was analyzed from a qualitative rather than a quantitative viewpoint as attempts to establish the reliability and validity of concept maps has been shown to be problematic in previous studies. In addition, when reviewing the scoring scheme please note that the

number of possible answers for each category was established using an expert concept map as a guide, however the expert map was not made available to participating students at any time during the study. The highest possible score was figured by multiplying the number of possible answers by the point value. The concept mapping exercise data takes the evaluation of the visual types and techniques used in this project a step beyond student perceptions by actually measuring learning outcomes. This data strongly indicated that student knowledge of introductory poultry production increased significantly because concept mapping exercises were imbedded into the courseware. Concept mapping acted as a tool for problem solving through the creation and invention of student mental models. Further, the student interviews plainly showed that students used other visualization types and techniques in order to complete their concept mapping exercises. Therefore it can be asserted that the inclusion of certain types and combinations of visualization positively impacts learning outcomes in web-based distance courses.

Category	Possible Answers	Point Value	Highest Possible
Valid Relationships	55	1	55
(Conceptual) Hierarchy	13	4	52
Cross-links	14	10	140
Examples	30	1	30

Table 1. Concept Mapping Scoring Scheme

		Average Number of Answers	
Category	Possible Answers	Pre	Post
Valid Relationships	55	0	0
(Conceptual) Hierarchy	13	2.81	9.20
Cross-links	14	0	11.20
Examples	30	7.47	10.35

Table 2. Changes in Concept Mapping Scores

Implications and Future Directions

A triangulation of all of the data gathered this study indicated that the inclusion of certain kinds and combinations of visualization types can be used to productively engage students and thereby positively impact learning outcomes for web-based courses. The benefits of most of the visualization types used in this study as teaching tools have been clearly established by previous studies. However, this study is unique as it examines the use and impact of traditional graphics used in combination with animations and concept mapping on student engagement and learning outcomes within web-based courses. Therefore, the findings of this study are significant.

To place this study further into context an additional review of the literature concerning the instructional effectiveness of web-based courseware was conducted. This review revealed that only a few good studies of this nature currently exist. The most significant of these studies evaluated teaching

practices within 486 educational web sites and concluded that use of the web caused teachers to choose ineffective teaching methods; of the courses sampled only 5.0% provided students with opportunities for problem solving, only 4.6% provided opportunities for creation and invention, whereas 52.5% left students with few options other than rotate memorization (Mioduser, Nachmias, Lahav and Oren, 2000, p. 63). Mioduser's, et al study did not examine web-based distance education courseware specifically, however their findings are still applicable to the study presented in this paper. Mioduser's, et al conclusions strongly support the argument that the courseware described in the preceding paragraphs was effective because it provided students with tools that prompt higher-level cognitive processes, such as problem solving and creation/invention.

In conclusion, the study presented in this paper is a single case study and as such cannot be broadly generalized. The results of one case study may be insightful, but the results of a series of case studies that examine the same topic would be more conclusive. Further case-based evaluation of the use of the visualization types and techniques presented in this paper is currently underway and will provide the opportunity for a meta-analysis of multiple case results.

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